Economic Assessment of a Conceptual Biomass to Liquids Bio-Syntrolysis Plant

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ABSTRACT

A series of assessments were performed to evaluate the economic efficiency of integrating a nuclear electric power plant with a biomass to SynFuel plant under market scenarios. Initial results suggest that a nuclear assisted-BioSyntrolysis Process would be as cost competitive as other carbon feedstock to liquid fuels concepts while having significant advantages regarding CO2 greenhouse gas production. This concept may also be competitive for those energy markets where fossil fuels are scarce and wind, hydroelectric, or other renewable energy can be produced at a relatively low cost. At this time, a realistic vision of this technology's deployment is a biomass to synfuel plants powered by a nuclear 1100 MWe reactor. Accompanying an area of 25 miles by 25 miles, this integrated Enterprise could produce 24,000 BBLs of SynFuel daily; or 0.2% of the U.S.'s imported oil.

Keywords: bio-syntrolysis, synfuel, greenhouse gas reduction

1 INTRODUCTION

A technical discussion of the carbon neutral, Bio-Syntrolysis process of converting biomass to liquid fuels is presented in the accompanying 2010 Clean Technology Conference & Expo paper, #924, *Process Modeling Results of Bio-Syntrolysis: Converting Biomass to Liquid Fuel with High Temperature Steam Electrolysis*, G.L. Hawkes, M.G. McKellar, M.M. Plum. This paper provides a limited discussion on the economic issues regarding economic efficiency, viability, and areas for improvement.

2 ANALYSIS METHODOLGY

An economic evaluation is one of management's tools used in acquiring, deploying, operating, and maintaining the productive resources of an economic organization. The purpose of this economic evaluation is to determine the economic consequences of developing a Bio-Syntrolysis, liquid fuels production process. With this as our goal, three basic questions must be answered:

- What is the most economically viable energy configuration for the Bio-Syntrolysis fuels plant?
- Is this configuration economically competitive with current or conventional synfuel solutions?
- And if not, what conditions would it require to be more viable?

2.1 The Model

The economic evaluation model is a product of two concepts: (1) the pro-forma and (2) the economic methodology of discounting. A pro-forma is simply a two-dimensional matrix of cost and revenue streams; time on one axis and cash flows on the other. Discounting (also known as present value analysis) is a process of reducing the estimated future value to a present value by a discount factor. Both concepts are ideally modeled within the two-dimensional configuration of Microsoft Excel 2007.

As the concept of Bio-Syntrolysis is in a pre-conceptual stage of development, projects in this stage in development are typically evaluated from a "top-down" process as little design data is available. However, because this process has been modeled quite extensively with many of today's engineering software packages, a significant amount of data regarding production processes was available; thus, an opportunity to develop a "bottoms-up" cost model.

In populating the model's input, two nagging issues were always present in estimating costs. First, though much research has been performed regarding Bio-Syntrolysis, there are no detailed drawings or specifications to develop a "nuts and bolts" capital cost estimate. The operational scenario suffers from this same issue. In short, our pre-conceptual phase of knowledge requires us to include significant cost contingencies to cover our lack of knowledge. Second, the volatility of the energy market and associated industries (oil, coal, natural gas, steel, and specialty metals) is significant and growing even more so in the last 5 years. Traditionally, energy prices were driven by the oil supplies and oil demands. Oil has proven to be a very fungible commodity as it is energy dense and easy to transport, it is safe to store and use, it is reliable in use and market, and compared to other energy sources, it has been a relatively low cost as supplies has always met its demands.

However, these advantages of oil as an energy source have now manifested into a problem of overconsumption. Because demand is often greater then supply, oil markets experience great price volatility due to the inelastic nature in oil consumption and production (inelasticity suggests great price changes with little change in supply or demand). At the same time, most of the world's oil reserves exist in politically unstable areas of the world; thus, as the stable economies of the world consume their oil resources, they must now rely on unstable oil suppliers. The point of this discussion is that volatility of the oil market and size of the capital investment required for this facility begs the investor to simulate the many possible market conditions to fully understand the risks of this investment.

For model development purposes, the investment was organized by chronological phase, plant functionality, and cost centers. This organization is often thought of as a life cycle analysis.

2.2 Pre-Operations Phase

The pre-operational phase (pre-ops) includes all of the activities required before production. These are organized into four broadly defined and parallel tasks of:

- Owner's & Engineering Activities
- Design Activities
- Capital Equipment Acquisition & Construction
- Testing & Ramp-up Activities

Of these four activities, the capital equipment acquisition and construction is the more expensive activity primarily due to our nth-of-a-kind assumption. The nth-of-a-kind assumption allows us to assume that the learning curve has minimized the cost of the owners, design, and ramp-up activities. Furthermore, this suggests that the majority of economies to scale have been captured; in effect, we can assume long-term price equilibrium.

2.2.1 Bio-Syntrolysis Island

The Bio-Syntrolysis process is a unique process where a carbon sources are gasified and accompanying heat is coupled to heat the steam in the production of hydrogen via the high-temperature steam electrolysis process (HTSE). Integral to this design is the injection of pure oxygen to maximize carbon monoxide (CO) production and minimize the carbon dioxide (CO2) production. Assuming the plant's electrical needs are produced from a CO2-free source and assuming the carbon feedstock would be biomass, the advantage of this biomass to liquids, Bio-Syntrolysis process the production of a sulfur-free, liquid transportation fuel that is essentially carbon neutral.

For evaluation purposes, the Bio-Syntrolysis plant was decomposed into seven major systems.

- Biomass Supply System
- Water Supply & Distribution System
- Hydrogen Supply & Distribution System
- Oxygen Supply & Distribution System
- Heat Recuperation & Distribution System
- Energy Distribution System
- Fuels Production System
- Product Management System

These major systems are then decomposed into lower level, subsystems. For example, the biomass supply system was then decomposed into a set of logically sequential subsystems, including:

- Pre-conditioned biomass receiving and transfer
- Pre-conditioned biomass storage
- Pre-conditioned biomass retrieval, transfer, conditioning, and transfer
- Conditioned biomass storage
- Conditioned biomass retrieval, transfer, and final delivery

From these subsystems, costs are parametrically estimated using data of similar processes or facilities from other industry sectors. All costs are then scaled according to a scaling factor. Assuming this estimating approach, the calculated cost estimate for a 24,000 BBL/day Bio-Syntrolysis plant is $1.563B or approximately $65.675k/BBL daily capacity of liquids production. Of this cost estimate, the HTSE plant is the primary cost driver at $465M for a plant rated at 5.75kg-H2/second (approximately $935k/day kg of h2 production). As a reference point, this capital cost estimate is approximately 25% higher than the combined capital cost of an oil sands project (approximately $17.5k/BBL daily capacity) and a crude oil refinery of similar size (approximately $35K/BBL daily capacity).

2.2.2 Energy Island

As the name suggests, the energy island's main function is to generate and transmit energy at the most cost efficient way while maintaining a carbon free status. In this analysis, four basic energy sources were considered, including: ownership of an 1100 MWe nuclear plant, ownership of a 4,400 MWe wind farm, the purchase 1000 MWe of power from a local grid, or a combination of these.

One of the primary considerations in the development of a Bio-Syntrolysis facility would be the availability of power. Currently, there are very few locations where a new consumer requiring 1100 MWe of dedicated electric power could be sited. For this reason, the large-scale development of five or ten Bio-Syntrolysis plants may be impossible due to the availability of a power supply. Simply stated, the production and transmission assets for electric power is not available, especially in rural locations where the majority of biomass would be produced. For this reason alone, the scenario of purchasing grid power was not evaluated.

The scenario of supplying energy from a green energy source (wind, solar, hydro) seems even less likely due to their current installed costs. For example, even if one assumes a very favorable installed cost of $2.0M/MW for wind energy, a 4400 MWe wind farm (which assumes a 25% production capacity factor) would require at least $8.8B for deployment, not including the cost of power transmission. Including transmission costs, this power supply could exceed $10.0B in overnight costs (about four times more expensive than a nuclear power plant. Other green sources of electric power are simply too expensive (such as solar) or are not available (such as hydro). For these reasons, a U.S. sited scenario using a green power source was not evaluated.

The nuclear plant scenario appears to be the only reasonable solution given the relative ease in deploying this reliable, dedicated energy source plus the advantage of no CO2 emissions. Given the industry's current Generation-III (Gen-III) design standard and associated plant life of 60 years, these reactors have projected overnight cost of $3.5M to $4.0M per MWe (two Gen-III plants are currently under construction at Southern Nuclear's Vogtle site at a project overnight cost of $3715/kW). Given these deployment advantages, a Gen-III reactor appears to be the better energy source for the Bio-Syntrolysis facility with a capital cost of $4.085B.

Generation-IV nuclear plants (High-Temperature Gas-Reactors) were also investigated but not included due to their cost disadvantage (at $5.5M-$6.0M/MWe, approximately 65% higher) when compared to the Gen-III cost. Further investigation also suggests Gen-IV reactors are simply the wrong application of this technology as they are designed to produce high-temperature, high-pressure heat - and though the Bio-Syntrolysis requires high-temp heat, it does not require an external source for this energy (the Bio-Syntrolysis process produces this type of heat by design.)

2.2.3 Balance of Plant

The Balance of Plant includes all of the support, indirect, and overhead equipment and facilities not captured or identified in the systems and subsystems. At this time, this would include site, roads, fencing, utilities, storm systems, general lighting, administration and office buildings, storage facilities, mechanical shops, fabrication shops, maintenance shops, etc. Both top-down and bottoms-up estimations with relatively equal results when considered as the final total estimated cost. In effect, a 7% adder as calculated on the total of the estimated islands and an estimation of the specific support and overhead functions resulted in a similar cost approximately $330M.

2.2.4 Contingency, PM, & CA

Given the pre-conceptual nature of this evaluation, costs for project contingency, public and community relations, system design and integration, project management, project engineering, contract administration, known-unknowns, and unknown-unknowns were included. At this time, all costs were applied as percentage of the calculated subtotal. In effect, a compounded contingency value of 25.7% or approximately $1.2B provides a cost allowance for the current lack of knowledge. Ideally, a preliminary design reduces this value to 10%.

2.3 Operations / Production Phase

The operations phase (ops) includes all of the activities during production. This has been organized into three broadly defined and parallel cost categories of:

- Fixed Operation Costs
- Variable Operation Costs
- Revenues

To be sustainable and economically efficient, revenues during operations must exceed the operating costs as pre-ops and post ops do not generate revenues by design.

2.3.1 Fixed Operation Costs

Fixed operation costs are those costs incurred during the operation phase and are constant at all scales of production – even zero production. Essentially, these costs are incurred to maintain a state of readiness even if nothing is produced. However, it is not a mothballed state. These costs include costs for minimum staffing (direct, indirect, support, overhead, supervisory, management), preventative maintenance, minimum energy loads, property taxes, and insurance.

Similar to the organization of pre-ops costs, fixed operation costs (a well as the variable operations costs) are organized by systems and subsystems. All costs are estimated from the bottoms-up. Direct labor costs are estimated according to number of shifts, management and supervisory staff, and finally direct operations staff. In general, if the size of the system / subsystem was expansive, the distance between systems / subsystems great, or the operations complex and regulated (as in a nuclear plant operation), it was assumed that this system / subsystem would require a dedicated staff versus a staff operating two systems / subsystems or more.

Consumable materials, energies, and maintenance were calculated per system / subsystem. Costs were determined for a low, expected, and high cost case. In 2010 dollars, the subtotal of fixed costs is approximately $320M. Of this, approximately $70M is for synfuels ops, $110M for insurance and property taxes, $40M for nuclear ops, and $25M for power production, $25M for biomass fuels, and the remaining for balance of plant.

2.3.2 Variable Operation Costs

Variable operation costs are those costs incurred during the operation / production phase and vary according to the scale of production. This includes staffing, operations and unplanned maintenance, materials and other consumables, operation services, income taxes, and unforeseen expenses. Similar to the fixed operation costs, all variable operation costs are estimated from the bottoms-up and are functionally related to the level of output. In 2010 dollars, the subtotal of variable costs is approximately $530M. Of this, $300M (approximately 56%) is for maintenance of the HTSE and $70M for the purchase of biomass. The remaining is for the balance of plant.

2.3.3 Revenues

Revenues from operations result from the sales of diesel and electricity sold at the assumed market price, a total of $1.045B in the first full year of ops. Although market prices fluctuate during the year and throughout the life of the investment, the model assumed average annual price for any given year, over time, based on an assumed escalation for diesel and electricity. Carbon-credits provided one more revenue stream at $5/ton.

In this analysis, a non-operations cash flow resulted after the depreciation of the synfuels plant and the sale of the nuclear power plant. This sale represents the residual value of a 60-year nuclear power plant investment. Typical of nuclear power technology, their services lives are longer due quality of construction, operations, and maintenance.

2.4 Post-Operational Phase

The post-operational (post-ops) phase follows the operations / production phase of the investment. During this phase, there is no production or sale of products although salvage value typically remains. The evaluation conservatively assumed the salvage value for the synfuels plant to be sufficient to return these lands to brown-field conditions. As required by the NRC, a nuclear plant requires funding assurance for the final phase of the plant; thus, a $260M assurance fund was established before operations for the decommissioning, decontamination, and demolition of the power plant.

3 EVALUATION RESULTS

Three standard, textbook tests of economic viability (simple payback, NPV, IRR) were used to evaluate the investment's economic viability. These tests do not guarantee success; they simply suggest an outcome of higher probabilities given future predictions.

Assuming current market conditions, the integrated LWR nuclear/Bio-Syntrolysis synfuel plant produces diesel at $3.50 / gallon, well above the current cost of diesel fuel production $2.25 to $2.50/gallon. However, current economic conditions may be short-lived if the world economies exist the 2007-2010 recession. Instead, if one assumes a slightly more productive economic picture and a modest 3% increase in world crude oil demand (84M-85M bpd versus 81M-82M bpd), crude oil prices could increase to $120-$150/BBL, resulting in $3.00-$3.50/gallon, assuming crude oil supply remains constant. Given any supply reduction or disruption, prices could climb well above this level, some predicting $200/BBL for crude and $8.00/gallon for diesel. Of course, these predictions are a contentious mix of economic and political uncertainties and long-term stability would be anyone's prediction.

This breakeven price of $3.50-$3.75/gallon equates to about $25.50-$27.25/MMBTU, a value comparable to energy cost of electricity at $0.085-$0.930/kWh which is close to the current average cost of residential electric energy and the primary energy source for electric and hybrid-electric vehicles.

4 CONCLUSION

This evaluation suggests a credible outcome for an integrated nuclear Bio-Syntrolysis synfuels plant. Moreover, the risk of this favorable outcome changing seems minimal as a majority of the costs and returns are well known. What is of risk is the predicted operation of the simulated yet unproven Bio-Syntrolysis technology. The prospect of this potentially favorable outcome suggests efforts be made to understand this technology better.

5 COPYRIGHT STATEMENT

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